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Emissions Testing of Industrial Processes Burning Hazardous Waste Materials

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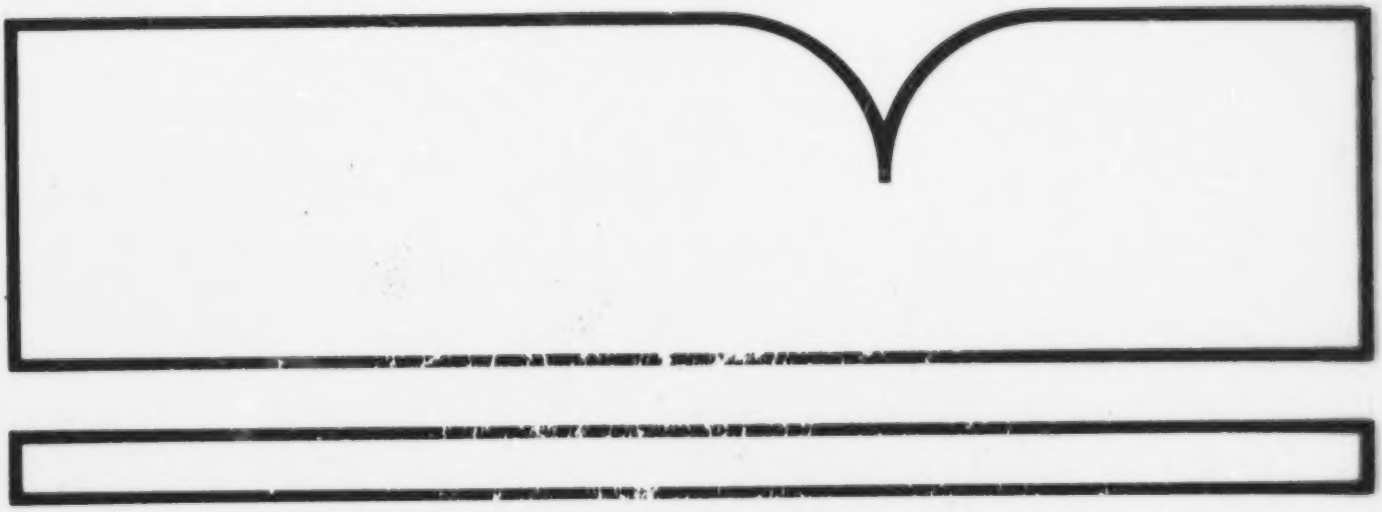

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EMISSIONS TESTING OF INDUSTRIAL PROCESSES BURNING HAZARDOUS WASTE MATERIALS

by

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The hazardous compounds burned ranged from non-halogenated solvents to high chlorinated materials such as trichloroethylene. Calculated destruction efficiencies for the hazardous compounds were in the range of from 99.929 to 99.9999.

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Hazardous waste incinerators are regulated under the Resource Conservation Recovery Act (RCRA). On the other hand processes that produce energy and only incidently burn hazardous waste materials are currently exempt from the RCRA incinerator regulations. EPA has initiated a Regulatory Impact Analysis (RIA) to determine if and to what degree regulation of such processes may be required. As part of the RIA study, EPA has conducted field tests of industrial processes that burn hazardous waste materials. This paper describes the testing and results of testing of two industrial boilers and a lime kiln that burned hazardous waste materials during the test program. Data on emissions and plant operating conditions that existed during emission measurements are presented.

The hazardous compounds burned ranged from non-halogenated solvents to high chlorinated materials such as trichloroethylene. Calculated destruction efficiencies for the hazardous compounds were in the range of from 99.929 to 99.9999.

INTRODUCTION

EPA's regulations for incineration of hazardous wastes require that incinerators must achieve a Destruction and Removal Efficiency (DRE) of at least 99.99 percent of the Principal Organic Hazardous Constituents (POHCs) present in the waste. Processes that primarily produce energy and incidentally burn hazardous wastes are currently exempt from the hazardous waste destruction performance regulations that apply to incinerators. These exempted processes include industrial boilers, kilns, and other industrial thermal processes, such as furnaces and ovens.

Even though industrial processes that burn hazardous wastes are exempt from incinerator regulations, EPA is conducting an investigation into the need for regulating such practices. A part of this investigation is a Regulatory Impact Analysis (RIA) which includes both technical and economic analyses.

This paper presents and discusses data obtained from three full-scale tests conducted by EPA. The test subjects were two industrial boilers and one industrial kiln.

For more background information on EPA's incineration program, boilers, and industrial processes, the reader is directed to references 1 through 6.

PERFORMANCE INDICES

While industrial processes are not currently regulated under the Resource Conservation and Recovery Act (RCRA) it is appropriate that their performance as hazardous waste material disposal systems be measured against EPA's incineration regulations. Specifically, these regulations for organic waste

destruction are:

$$DRE = \frac{Win - Wout}{Win} \times 100 \geq 99.99 \text{ percent}$$

where

Win = Mass flowrate of a POHC in the waste fuel.

Wout = Stack emission rate of a POHC.

In addition, emissions of criteria pollutants such as carbon monoxide (CO), oxides of nitrogen (NO_x), hydrocarbon (HC), and particulate matter are important measures of combustion performance acceptability and correlation of these parameters with organic waste destruction efficiency is a major goal of EPA's research into hazardous waste combustion. While not regulated even for incinerators, emissions of Products of Incomplete Combustion (PICs), which are breakdown products from POHC destruction, are significant measures of total organics destruction. Since many hazardous waste compounds are chlorinated materials, emissions of hydrochloric acid (HCl), which are regulated under the RCRA incinerator regulations, are also measurement targets.

SAMPLING AND ANALYTICAL PROTOCOLS

The sampling requirements for waste combustion testing were sufficiently complex that three separate stack sampling trains were used. Continuous monitor with strip chart recorders were used for gaseous emission species measurement. In addition, extensive periodic waste and primary fuel sampling was required. While subtle variations in protocol were required to accommodate differing site and waste characteristics, the sampling and analytical procedures were basically as described below.

Figure 1 describes the Modified EPA Method 5 train that was used to collect semivolatile organics (boiling point >100°C) and particulate matter (7). The semivolatile materials were collected on XAD-2 resin that was analyzed for POHC and PIC material by GC/MS.

Figure 2 is a schematic of the Volatile Organic Sampling Train (VOST) that was used to collect volatile organics for subsequent GC/MS analysis (8). The heart of this train consists of two resin traps in series. The first resin trap contains TENAX and the second resin trap contains TENAX with an activated charcoal backup.

Figure 3 depicts the Method 6 train used to collect HCl emissions (7). Analysis was conducted by titration of the impinger solution.

Table 1 describes the continuous monitoring equipment used to record gaseous emissions (9). C_1 through C_6 hydrocarbons were collected in a stainless steel cylinder and analyzed in an onsite gas chromatograph.

Waste and fuel samples were collected at half-hour intervals and composited. The composited samples are analyzed by GC/Hall and GC/FID for POHCs and for total chlorides, C,H,N,O,S, and HHV by ultimate analysis ASTM methods.

For all tests, trip and field blanks were used for the resin cartridges. In addition, laboratory blanks were used to ascertain the absence of laboratory contamination.

For each test series, background tests were conducted with the primary fossil fuel alone (no hazardous waste materials). For most tests, waste materials of particular interest were "spiked" (added) to the waste material normally

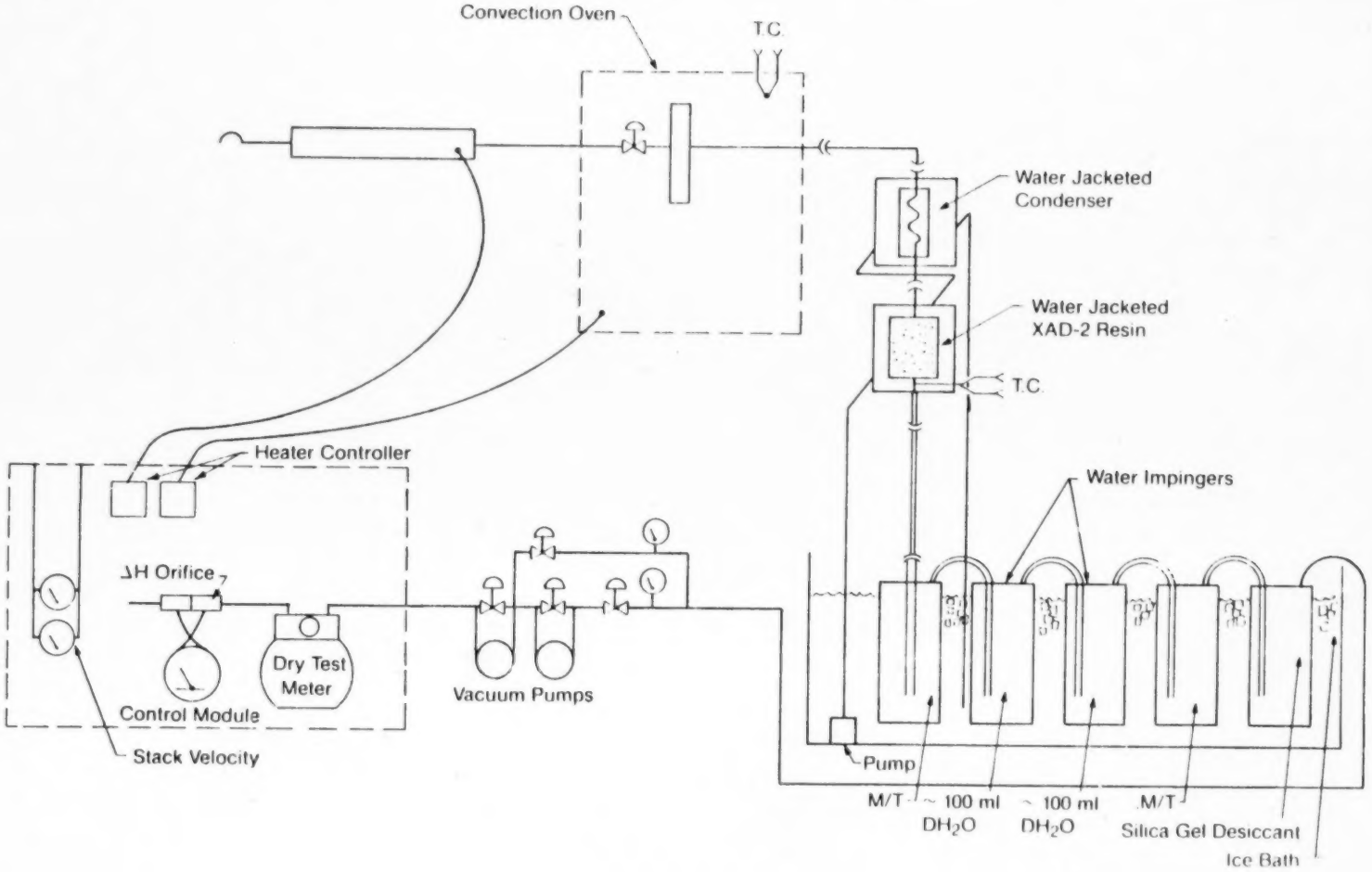


FIGURE 1 - Modified EPA Method 5 Train

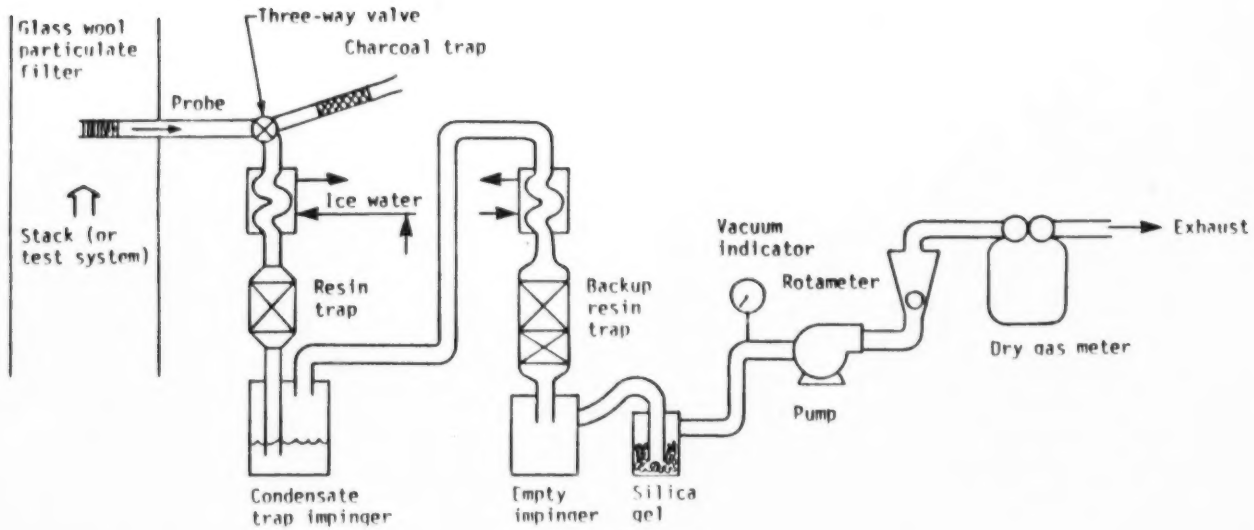
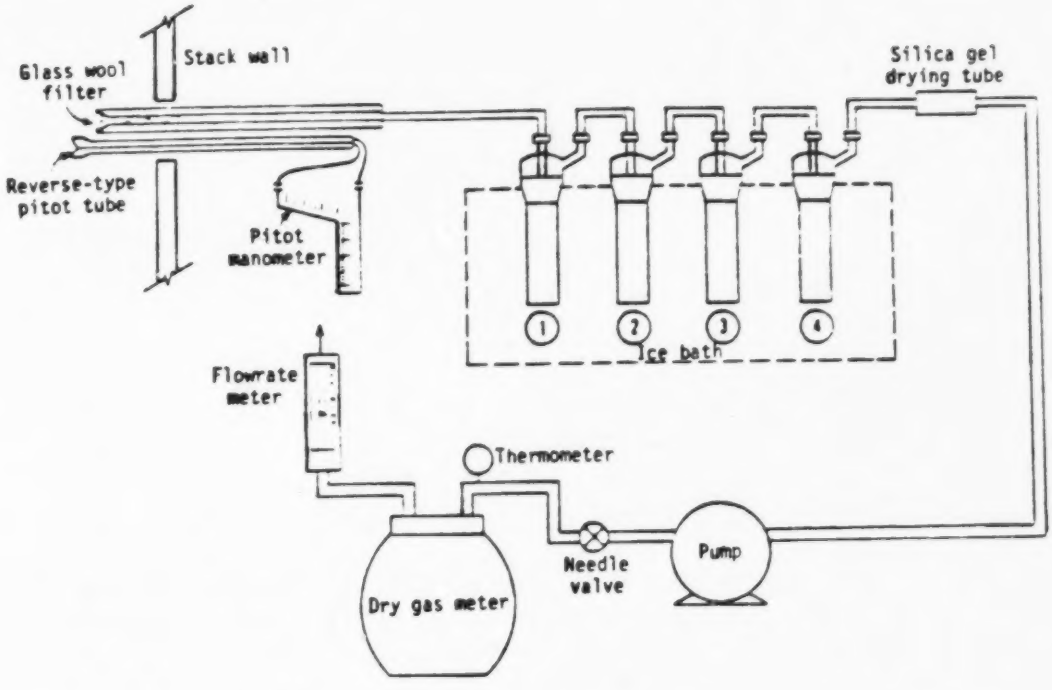


FIGURE 2 - Schematic Diagram of Volatile Organic Sampling Train



① & ② Midget impinger (15 mL of 0.1 N NaOH)
③ Midget impinger (15 mL of 3 percent H_2O_2)
④ Midget impinger (dry)

FIGURE 3 - Schematic Diagram of Hydrogen Chloride Sampling Train

TABLE 1 - CONTINUOUS MONITORING EQUIPMENT

Instrument	Principle of Operation	Manufacturer	Instrument Model	Range
NO NO_x	Chemiluminescence	Thermo Electron	10 AR	0-100 ppm 0-500 ppm 0-1,000 ppm 0-5,000 ppm
CO	Nondispersive infrared (NDIR)	ANARAD	500R	0-1,000 ppm
CO_2	Nondispersive infrared (NDIR)	ANARAD	AR500	0-20 percent
O_2	Fuel cell	Teledyne		0-5 percent 0-25 percent
Total hydrocarbon	Flame ionization detector (FID)	Beckman	400	0-1 ppm 0-10 ppm 0-100 ppm 0-1,000 ppm 0-10,000 ppm 0-1 percent 0-2 percent
Sample gas conditioner	Refrigerant dryer-condenser	Hankinson	E-4G-SS	10 scfm
Strip chart recorder	Dual-pen analog	Linear	400	0-10 mV 0-100 mV 0-1 V 0-10 V

burned to facilitate data interpretation and to allow comparison across the combustor types. The spike materials usually consisted of chlorinated organic materials such as carbon tetrachloride, 1,1,2 trichloroethylene, and chlorobenzene.

INDUSTRIAL BOILER TESTS

The industrial boiler tests described here were conducted as part of a 12-test series of full-scale boiler tests to support EPA's Regulatory Impact Analysis (RIA) effort for industrial boilers. The two tests selected here are the farthest along in data interpretation. For the sake of brevity, the test descriptions will be greatly condensed and not all data from all test sets conducted at each test site will be described. In return for their participation in this voluntary test program, each boiler site has been guaranteed anonymity so the boilers will only be identified by numbers.

BOILER NUMBER ONE

Industrial boiler number one was a forced draft packaged watertube A-type Combustion Engineering boiler. Its maximum steam load capacity is 13.9 kg/s (110,000 lb/hr)of superheated steam at 2.94 MPA (425 psig) and 315°C (600°F). The unit, installed in 1971, is equipped with one dual air register gas and oil fired COEN burner. The furnace has a volume of 41.9 m^3 (1480 ft^3) and a heating surface of 665 m^2 (7158 ft^2) providing volumetric and surface heat release rates of 862 KW/m^3 (81,700 Btu/hr ft^3) and 52.7 KW/m^2 (16,950 Btu/hr ft^2) respectively at maximum heat input capacity. Combustion air is not preheated and the flue gas is not treated for particulate control. Typical operating steam load is approximately 6.3 kg/s (50,000 lb/hr).

The boiler was retrofitted to fire organic wastes produced at the site. Waste fuel is injected through two guns located on either side of the center fuel oil gun. Each waste gun tip has three nozzles positioned such that the waste fuel spray is diverted away from the main fuel oil spray. Both oil and wastes are steam atomized.

The test series, described here consisted of five tests, one baseline and four cofiring tests. The baseline fuel was No. 6 oil. During the second test heat input from the No. 6 oil was supplemented with the waste fuel available at the site. This waste, a process production bottom, contained methyl methacrylate (MMA) as the POHC of interest. During tests 3 through 5, the MMA waste fuel was artifically spiked with chlorinated POHCs, namely carbon tetrachloride (CCl_4), chlorobenzene (ClΦ), and trichloroethylene (TCE).

Table 2 summarizes the salient operating conditions of the boiler during the tests. Increases in excess combustion air were generally required during cofiring conditions. Excess O_2 measured by boiler control room meter averaged 3 percent during baseline and was increased to a range of 4 to 6 percent during cofiring. These higher combustion air levels during waste fuel burning were implemented to maintain smoke emissions at a minimum. Despite this measure, several smoke emission episodes occurred during flue gas emissions testing, as noted in Table 2.

Table 3 describes the waste fuel analysis for the major POHCs. Data presented in Table 3 represent the arithmetic averages of duplicate analysis.

Table 4 provides a summary of POHC emission rates for the cofiring tests. The data presented are arithmetric averages of individual Tenax test runs.

Boiler No. 1

TABLE 2. Boiler Operating Summary

Primary and Waste Fuels	No. 6 Oil (Baseline)	No. 6 Oil and Bottoms	No. 6 Oil and Chlorinated Bottoms		
	Test 1	Test 2	Test 3	Test 4	Test 5
Steam flow, kg/s (10^3 lb/hr)	6.8 (54)	7.0 (56)	7.0 (56)	7.0 (56)	6.9 (55)
No. 6 oil flow, ml/s (gpm)	515 (8.18)	448 (7.12)	352 (5.59)	375 (5.95)	358 (5.68)
Waste fuel flow, ml/s (gpm)	0	195 (3.10)	236 (3.75)	260 (4.13)	250 (3.97)
Total heat input, MW (million Btu/hr)	21.8 (74.2)	24.0 (82.0)	20.6 (70.4)	22.3 (76.0)	21.0 (71.6)
Waste fuel heat input (percent of total)	0	(21)	(28)	(29)	(28)
Boiler out O_2 (percent dry)	(3.0)	(3.9)	(4.4)	(6.0)	(5.9)
Number of smoke emission episodes[a]	0	1	8	4	3

[a] Number of recorded smoke alarms. Ringelman number $\geq$ 0.6 during smoke alarm.

Boiler No. 1

TABLE 3. Waste Fuel Analysis Results[a], mg/ml

Compound	Bottoms	Chlorinated Bottoms		
	Cofiring Test 2	Cofiring Test 3	Cofiring Test 4	Cofiring Test 5
CCl_4[b]	ND	27.7	28.7	29.1
Clϕ	ND	16.5	15.9	16.1
TCE[b]	ND	28.7	29.4	28.9
MMA[b]	34.1	37.5	33.0	49.7

ND - Not detected (concentration is below detection limit)

[a]All numbers represent the arithmetic average of duplicate analysis.

[b]POHC's per RCRA Appendix VIII list (May 1980)

Boiler No. 1

TABLE 4. Summary of POHC Emission Rates, μg/s

Test Description	No. 6 Oil and Bottoms	No. 6 Oil and Chlorinated Bottoms		
	Test 2	Test 3	Test 4	Test 5
Carbon Tetrachloride (CCl_4)	77	29	18	21
Chlorobenzene ($Cl\phi$)	2.8	190	4	29
Trichloroethylene (TCE)	38	140	36	47
Methyl methacrylate (MMA)	220	4,000	1,400	375

Numbers are arithmetic averages of individual Tenax test runs. All emissions are blank corrected.

ND -- Usually signifies that blank value was greater than sample value in which case compound was determined to be at concentrations less than detection limit (5 to 10 ng per sample corresponding to 2 to 4 μg/s

Boiler No. 1

TABLE 5. Summary of DRE Calculations

Test Description	No. 6 Oil and Bottoms	No. 6 Oil and Chlorinated Bottoms		
	Cofire Test 2	Cofire Test 3	Cofire Test 4	Cofire Test 5
Carbon tetrachloride	NA	99.9995	99.9998	99.9997
Chlorobenzene	NA	99.995	99.9999	99.9993
Trichloroethylene	NA	99.998	99.9995	99.9994
Methyl methacrylate	99.997	99.95	99.98	99.997

NA - Not applicable. Chlorinated compounds were not added to waste fuels during this test.

All emissions are blank corrected. Table 5 displays the calculated DREs of the major POHCs for the cofiring test runs. Table 6 describes the criteria gaseous emissions measured for each test. Data in Table 6 represent the average measured values for each test (10).

BOILER NUMBER TWO

Industrial boiler number two was a balanced draft Babcock and Wilcox water-tube boiler with a rated steam capacity of 7.6 kg/s (60,000 lb/hr) of saturated steam at 1.4 MPa (200 psig). This boiler, orginially designed for coal burning, is equipped with two B&W circular burners arranged in two levels, each capable of burning No. 6 oil, No. 2 oil, natural gas, or propane.

The boiler is normally cofired with a purge thinner originating from the purging of paint spray guns. The waste solvent is introduced through a separate pressure-atomized y-jet B&W oil gun near the center of the lower burner. The firing rate of the purge thinner is generally limited to approximately 31 ml/s (30 gph) and automatically shuts off when the boiler steam load falls below 3.8 kg/s (30,000 lb/hr). For this test, the cutoff point was lowered to 2.5 kg/s (20,000 lb/hr).

The test program consisted of four tests: one baseline and three cofiring tests. The baseline fuel was No. 6 fuel oil. During the cofiring test, the fuel oil was supplemented with purge thinners. The purge thinner was spiked with carbon tetrachloride (CCl_4), trichloroethylene (TCE), and chlorobenzene (ClΦ).

Some problems were experienced with feeding and operation of the boiler. The chlorinated compounds did not mix well with the thinner and their concentration

Boiler No. 1

TABLE 6. Criteria Gaseous and Particulate Emissions

Stack Emission	Units	Test Number and Description: No. 6 Oil	No. 6 Oil and Bottoms	No. 6 Oil and Chlorinated Bottoms		
		1	2	3	4	5
O_2	percent	3.8	5.5	6.4	7.0	7.2
CO_2	percent	12.3	11.6	11.2	10.3	10.2
CO	ppm	87	97	135	129	138
	ng/J[d]	30	33	46	44	48
NO	ppm	278	378	431	439	413
	ng/J (as NO_2)	156	212	241	246	235
SO_2	ppm	276	196	182	184	205
	ng/J[d]	216	153	142	143	162
HC (C_1 to C_6	ppm	37	142	91	37	144
	ng/J (as C_1)	7.1	28	18	7.2	28
HCl	ng/J	7.0	3.5	324	292	371
	(lb/hr)	(1.2)	(0.8)	(53.0)	(51.6)	(61.7)
Particulate Mass	ng/J	13.9	13.6	19.5	14.7	15.0
	(lb/hr)	(2.56)	(2.56)	(3.23)	(2.66)	(2.55)

tion tended to increase over time. During the final day of testing, the concentration of the chlorinated compounds was reduced as additional thinner was added to the mixing tank to maintain uninterrupted flow to the boiler. Shortly after the third test, the boiler was shut down due to a coked oil gun. The gun was cleaned and reinserted further into the boiler. During the final day to testing, the other oil gun exhibited the same problem and shut down the boiler. The boiler was brought back online after cleaning and repositioning the gun further into the boiler. After both guns were inserted further into the boiler, the problems were corrected.

Table 7 describes the operating conditions of the boiler during the tests. The purge thinner ranged from 9 to 10 percent of the total heat input. The high excess air levels are typical of the operation of this boiler, but are likely to be well above design specifications.

Table 8 summarizes the POHC content of the waste and spiked feeds. Toluene was the primary POHC material in the thinner.

Table 9 presents the calculated DRE's achieved during the tests. Table 10 summarizes the criteria gaseous and particulate emissions, on an average basis, for each test (11).

LIME KILN

Lime kilns provide a combustion environment similar to that required for hazardous waste incineration. Such kilns typically operate at temperatures above 1093°C (2000°F), have gas residence times in excess of 1.5 seconds, and have a highly turbulent combustion zone.

Boiler No. 2

TABLE 7. Boiler Operating Conditions

Parameter	Test 1 Baseline	Test 2 Cofire	Test 3 Cofire	Test 4 Cofire
Steam flow, kg/s (1,000 lb/hr)	4.0 (32)	4.0 (32)	4.0 (32)	4.0 (32)
Air flow, kg/s (1,000 lb/hr)	4.9 (39)	5.2 (41)	5.2 (41)	4.8 (38)
Excess Air (percent)	66	59	63	65
Oil flow, liter/sec (gph)	0.251 (239)	0.215 (204)	0.220 (209)	0.210 (200)
Thinner flow, liter/sec (gph)	--	0.028 (27)	0.035 (33)	0.030 (29)
Windbox pressure, Pa (in. H_2O)	250 (1.0)	270 (1.1)	300 (1.2)	300 (1.2)
Furnace draft, Pa (in. H_2O)	-19 (-0.075)	-17 (-0.067)	-16 (-0.065)	-20 (-0.08)
Uptake draft, Pa (in. H_2O)	-93 (-0.373)	-97 (-0.39)	-100 (-0.41)	-92 (-0.37)
Drum level, Pa (in. H_2O)	160 (0.64)	141 (0.57)	134 (0.54)	190 (0.75)
Steam header pressured, kPa (psig)	814 (118)	814 (118)	814 (118)	814 (118)
Stream burner pressure, kPA (psig)	717 (104)	717 (104)	717 (104)	717 (104)
Oil pump pressure, MPa (psig)	1.48 (215)	1.48 (215)	1.48 (215)	1.48 (215)
Oil burner pressure, kPa (psig)	320 (47)	300 (43)	300 (44)	290 (42)
Thinner header pressure, kPA (psig)	--	170 (24)	170 (25)	170 (25)
Thinner burner pressure, kPA (psig)	--	170 (25)	180 (26)	180 (26)
Steam pressure, kPA (psig)	869 (126)	869 (126)	876 (127)	976 (127)
Efficiency, precenta	79.6	79.0	78.7	79.2

a By ASME heat loss method

Boiler No. 2

TABLE 8. Volatile Organic Composition of Thinner (grams per liter)

Compound	Unspiked Thinner	Test			
		2	3	4	5
RCRA Appendix VIII					
Carbon tetrachloride*	<1	20.8	29.8	30.0	29.5
Trichloroethylene*	<1	7.8	48.6	61.4	49.2
Chlorobenzene*	<1	1.29	5.6	5.8	3.5
Toluene	13.75	10.2	11.8	8.7	4.6

*Added to the thinner for purposes of this test

Boiler No. 2

TABLE 9. DRE's of POHCs

DRE's (percent)	TCE	Clϕ	CCl_4	Toluene
Test 2	99.97	99.96	99.985	99.885
Test 3	99.993	99.99	99.929	99.975
Test 4	99.998	99.987	99.999	99.975

Boiler No. 2

TABLE 10. Criteria Gaseous and Particulate Emissions[a]

Emission	Test 1 Baseline	Test 2 Cofire	Test 3 Cofire	Test 4 Cofire
O_2, percent[b]	8.6	8.1	8.5	8.5
CO_2, percent[b]	9.0	8.7	8.9	9.1
CO, ppm[c]	135	139	109	--
ng/J[d]				
NO, ppm[c]	328	275	299	243
ng/J (as NO_2)[d]	(271)	(254)	(268)	(214)
Particulate mass, ng/J[d]	7.61	36.5	411	44.7
(g/dscm)	(0.0176)	(0.0755)	(0.0876)	(0.0973)
HCl[e], ng/J[d]	36.8	97.9	269	495
(lb/hr)	(2.87)	(7.73)	(22.05)	(38.4)

[a]Average for each test
[b]Percent dry basis
[c]All ppm measurements corrected to 3 percent O_2, dry
[d]ng/J on heat input basis
[e]Average of two measurements per test

In 1983, the State of Wisconsin Department of National Resources (DNR) and EPA Region V issued a temporary permit to Rockwell Lime Company to conduct a hazardous waste test burn. The test would allow the burning of hazardous liquid waste as supplemental fuel along with petroleum coke. The waste fuel would replace natural gas as a fuel component.

The industrial process involves the heating of limestone to a temperature of approximately 1093°C (2000°F) in a horizontal rotary kiln to prepare the lime product. The calcining is achieved by interfacing the hot gases with the limestone, which drives off the CO_2 from the limestone, leaving the lime product (CaO).

Figure 4 is a schematic diagram of the lime kiln process. The kiln, with refractory lining, is 2.4 m (8 ft) in diameter and 67.1 m (220 ft) long. The kiln rotates slowly (approximately 1 rpm) and has a slope of 6 cm/m to allow material to pass through by gravity. The kiln has a countercurrent flow pattern. Solid materials travel in one direction and hot gases and dust emissions in the opposite direction. Limestone is fed into the kiln at the upper end at a rate of approximately 15,440 kg/hr (34,000 lb/hr). At the opposite end of the kiln, a mixture of coal and natural gas is burned at the rates of approximately 1,450 kg/hr (3200 lb/hr) and 142 m^3/hr (5000 ft^3/hr), respectively, to provide a heat content of approximately 14,700 kw (50 M Btu/hr).

During the waste fuel test burns, waste fuel was substituted for the natural gas and fed to the kiln approximately 2.3 to 11 L/min (0.6 to 2.9 gal/min). As the limestone feed travels down the inclined rotating kiln, it passes through

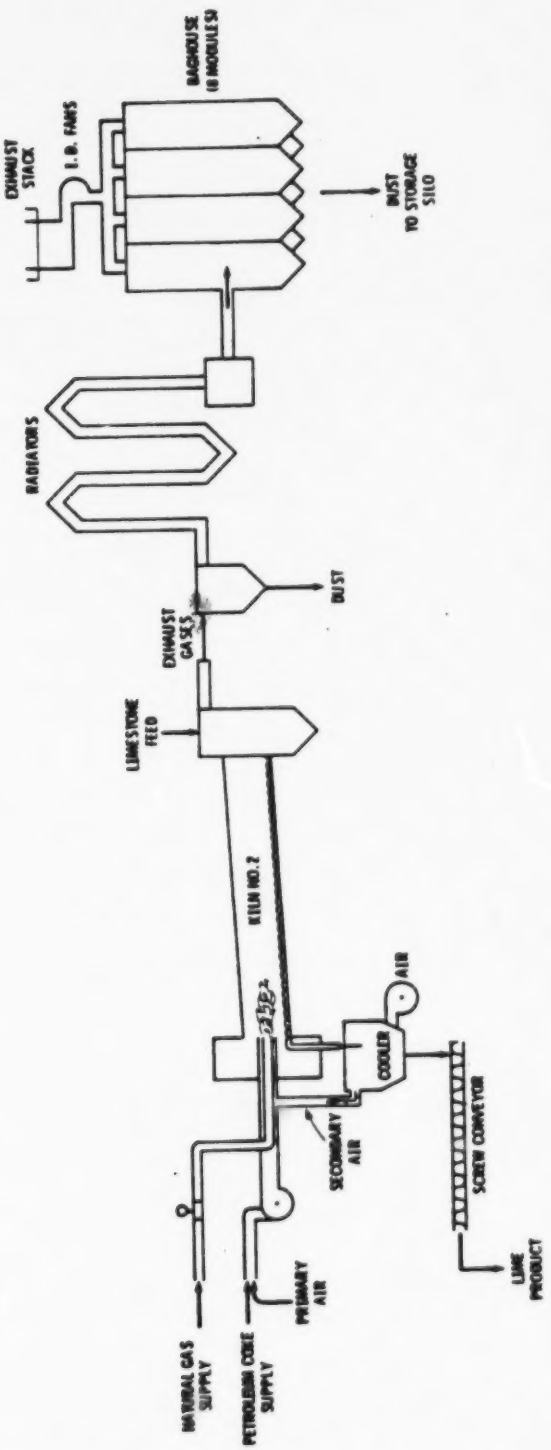


FIGURE 4. Schematic diagram of lime kiln process.

various temperature zones and the hot gases calcine the limestone into the lime product. The product is produced at a rate of approximately 7720 kg/hr (17,000 lb/hr).

In addition to observing the lime product as it exits the kiln, the kiln operators observe air flow rates and temperatures, limestone feed rates, coke and natural gas feed rates, kiln rotational speed and temperature, baghouse pressures, storage silo capacities, and the percent oxygen and percent combustibles of the kiln exhaust gases. Gas flows out the stack at approximately 200°C (392°F) and 5.5 m/s (18 ft/s). During the waste test, sampling was conducted at the stack except for process samples taken from the kiln.

The fuel fired during baseline conditions was a blended combination of petroleum coke and natural gas. Gas was fed to the kiln through a center burner tube (1 in dia.) and coke was fed through an eccentric (1 ft dia.) outer tube. During waste fuel conditions, a 1-inch diameter stainless steel pipe was placed on the burner pipe and its nozzle pointed into the flame. The waste fuel replaced the natural gas and the waste feed and petroleum coke were fed unblended into the kiln.

The waste fuel consisted primarily of solvents from lacquer thinners, alcohols, still bottoms, paint wastes, and 0.40 percent chlorinated hydrocarbons. Additional chlorinated organics (tetrachloroethylene and trichloroethylene) were spiked to the waste fuel to bring the total chlorine content to approximately 3.0 percent. The waste fuel ranged from 8 to 36 percent of the heat input to the kiln. The major POHC materials were methylene chloride ($MeCl_2$), methyl

ethyl ketone (MEK), trichloroethane (CH_3CCl_3), trichloroethylene (TCE), and Toluene.

Table 11 describes the waste fuel conditions for the test runs. Table 12 summarizes the mass feed rate of POHCs out. Table 13 displays the DRE calculated for the major POHCs. Table 14 presents the continuous monitoring results and particulate measurements.

Under normal conditions, the lime kiln operators maintain the O_2 content in the kiln at low levels (<1.5 percent). However, after the switch was made from gas to waste fuel, consistent kiln operations could not be maintained. CO emissions fluctuated, O_2 levels increased, and on a few occasions lime product quality problems were encountered (12).

CONCLUSIONS

For both the boiler tests and the kiln test, the measured waste destruction efficiencies were in the vicinity of that required under the RCRA incinerator regulations. The processes tested under this program, if operated under identical conditions, with identical wastes, and at similar waste concentrations to those used during these tests, should achieve similar waste compound destruction efficiencies.

It must be noted, however, that during the waste tests, the processes were not operated in a normal mode. Boiler parameters such as load and excess air rates were held constant during each test run to ensure uniform conditions for the required 3-hour sampling period. During "upset" periods such as smoke incidents or CO excursions, the sampling probes were pulled from the stack until

Lime Kiln

TABLE 11. Waste Fuel Conditions

Run No.	Date	Chlorine content, % (vol.)	Sulfur content %	PCB concentration, ppm	Heat value, Btu/lb	Specific gravity g/cc	Feed rate L/min	Feed rate gal/min	Mass rate g/min	Mass rate lb/min
1	05/02/83	3.14	0.10	1.0	12,301	1.031	2.42	0.64	2,498	5.50
							3.3	0.89	3,473	7.65
2	05/03/83	2.66	0.08	1.0	12,084	1.042	4.58	1.21	4,772	10.51
3	05/04/83	3.04	0.065	1.0	12,267	1.035	7.70	2.05	8,023	17.67
4	05/05/83	3.05	0.06	1.0	13,612	0.986	2.95	0.78	2,911	6.41
							10.98	2.90	10,823	23.84
5	05/06/83	3.51	0.11	1.0	14,064	0.971	10.40	2.88	10,585	23.32

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TABLE 12. Mass Emission Rates - POHC's Out

	$MeCl_2$	MEK	1,1,1 Trichloro-ethane	TCE	PERC	Toluene
Test 1	16.9	41.1	31.0	65	9.1	64.7
2	23.7	52.6	10.2	12.2	6.5	120.8
3	5.4	41.7	22.0	20.5	12.7	138.0
4	13.7	102.3	48.0	17.5	38.0	374.3
5	11.6	91.3	91.5	47.3	82.0	373.3

TABLE 13. DRE vs. POHC

	$MeCl_2$	MEK	1,1,1 Trichloro-ethane	TCE	PERC	Toluene
Test 1	99.9947	99.9994	99.9955	99.9998	99.9998	99.9998
2	99.9949	99.9996	99.9982	99.9997	99.9999	99.9998
3	99.9995	99.9997	99.9975	99.9998	99.9999	99.9998
4	99.9985	99.9992	99.9962	99.9999	99.9997	99.9995
5	99.9995	99.9997	99.9969	99.9998	99.9997	99.9997

TABLE 14. Summary of Continuous Monitoring Results

Run	CO (ppm)	SO_2 (ppm)	NO_x (ppm)	O_2 (%)	THC (ppm)
Base	1,034	-	348	-	8.4
Base	45	528	345	8.2	-
Base	200	557	437	6.1	-
1	32	492	439	6.2	3.9
2	224	540	507	5.6	3.0
3	557	637	469	5.0	3.5
4	1,060	650	439	5.3	3.8
5	1,357	672	258	6.0	3.6

steady state conditions were regained. Boilers, of course, generally operate in a load demand mode. This test program provides no information on the impacts of load variation and transitions between load points on POHC DREs.

For the lime kiln, it was noted that consistent kiln operation could not be maintained and that product quality occasionally suffered. Of course, in actual practice, product quality is the prime operational concern. During the short span of the testing program it was not possible to explore operating conditions that could result in consistent product quality during waste firing. The effects on POHC DRE of the changes in operating conditions required to insure product quality are not known.

For both boilers and kilns the data on the emissions of products of incomplete combustion (PICs) are still being analyzed. Although these emissions were measured during the boiler and kiln tests, the data is not yet in a form adequate for presentation.

On balance, well operated boilers and lime kilns appears to hold considerable promise for hazardous waste material destruction. The opportunity cost savings from not having to construct a separate waste disposal facility are considerable and significant fuel cost savings could be provided by firing high heating value fuels. The nature of the processes impose some conditions that will bias operations toward achieving high DREs. For example, boilers must maintain steam producing temperatures and cannot accept large quantities of the difficult to destroy chlorinated compounds due to the highly corrosive effect of the concommitant hydrochloric acid (HCl) on boiler internal components.

Lime kilns exhibit some senitivities to high halogen contents and also must operate at sufficiently high temperatures to produce calcining conditions.

FURTHER WORK

The boiler and kiln tests described here are components of broader programs being conducted by EPA. Other such source tests have been conducted and additional tests of industrial processes are planned. Also tests of such processes will be conducted under non-steady state conditions to determine which conditions constitute an acceptable operating envelope for those processes when hazardous waste materials are fired.

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